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(54) **SEAMLESS SEGMENT ROUTING FOR MULTIPROTOCOL LABEL SWITCHING (MPLS) INTERWORKING**

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H04L 45/745	(2022.01)
H04L 45/741	(2022.01)
H04L 45/24	(2022.01)

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CPC ***H04L 45/20*** (2013.01); ***H04L 45/24*** (2013.01); ***H04L 45/42*** (2013.01); ***H04L 45/741*** (2013.01); ***H04L 45/745*** (2013.01); ***H04L 69/22*** (2013.01)

(58) **Field of Classification Search**
CPC H04L 45/20; H04L 45/24; H04L 45/42; H04L 45/741; H04L 45/745; H04L 69/22
See application file for complete search history.

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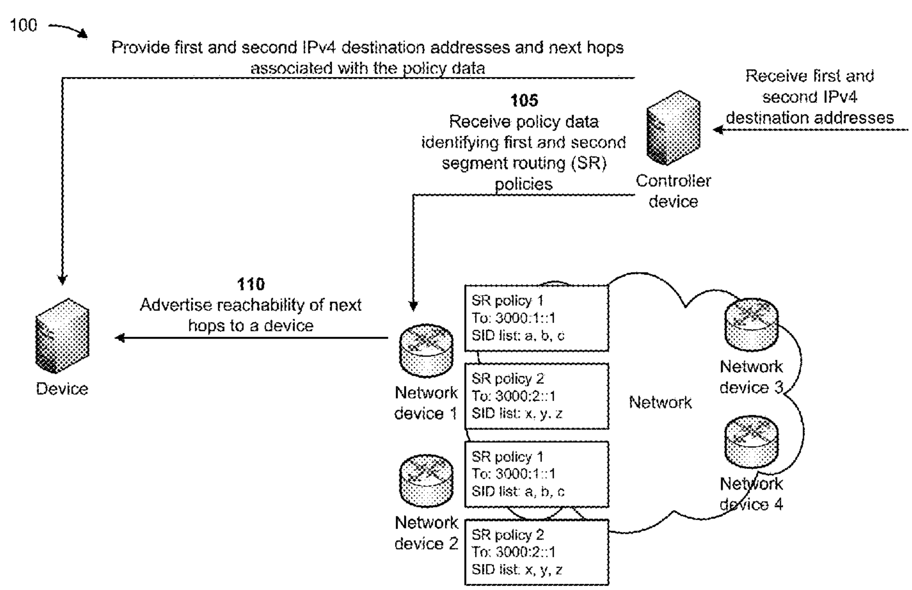
(57) **ABSTRACT**

A network device may receive policy data identifying a first segment routing (SR) policy and a second SR policy. The first SR policy may be associated with a first path through a network and a first next hop, and the second SR policy may be associated with a second path through the network and a second next hop. The network device may advertise, to another device, reachability associated with the first next hop and the second next hop, and may receive, from the other device, a packet with a header. The network device may determine, from the header, data identifying the first next hop or the second next hop, without performing a lookup, and may cause the packet to be routed to a destination address, via the first path or the second path, based on the policy data associated with the first next hop or the second next hop.

20 Claims, 9 Drawing Sheets



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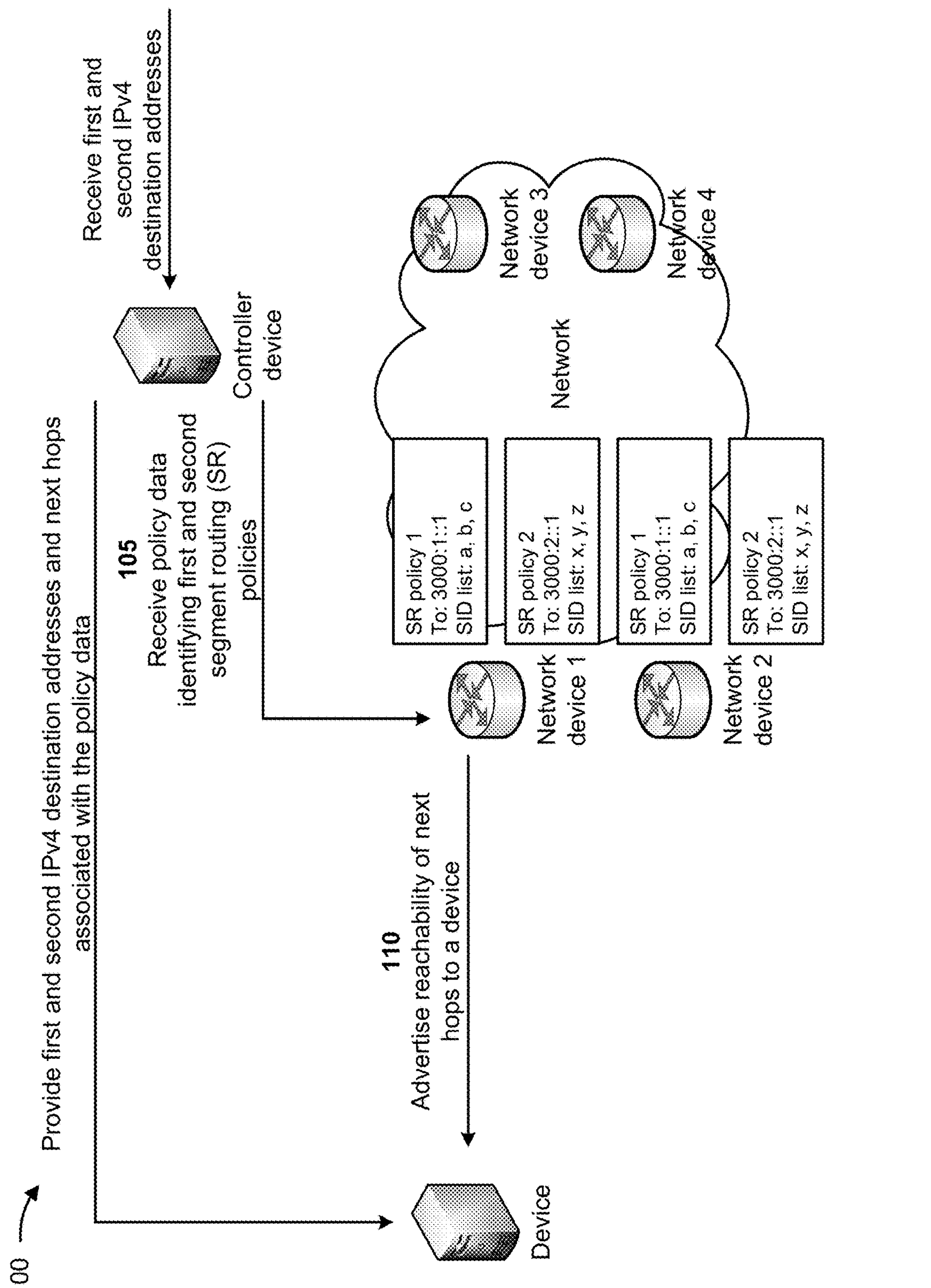
100
Receive first and second IPv4 destination addresses
Controller device
Provide first and second IPv4 destination addresses and next hops associated with the policy data
105
Receive policy data identifying first and second segment routing (SR) policies
Network
Network device 3
Network device 4
SR policy 1
To: 3000:1::1
SID list: a, b, c
SR policy 2
To: 3000:2::1
SID list: x, y, z
SR policy 1
To: 3000:1::1
SID list: a, b, c
SR policy 2
To: 3000:2::1
SID list: x, y, z
Network device 1
Network device 2
110
Advertise reachability of next hops to a device
Device

FIG. 1A

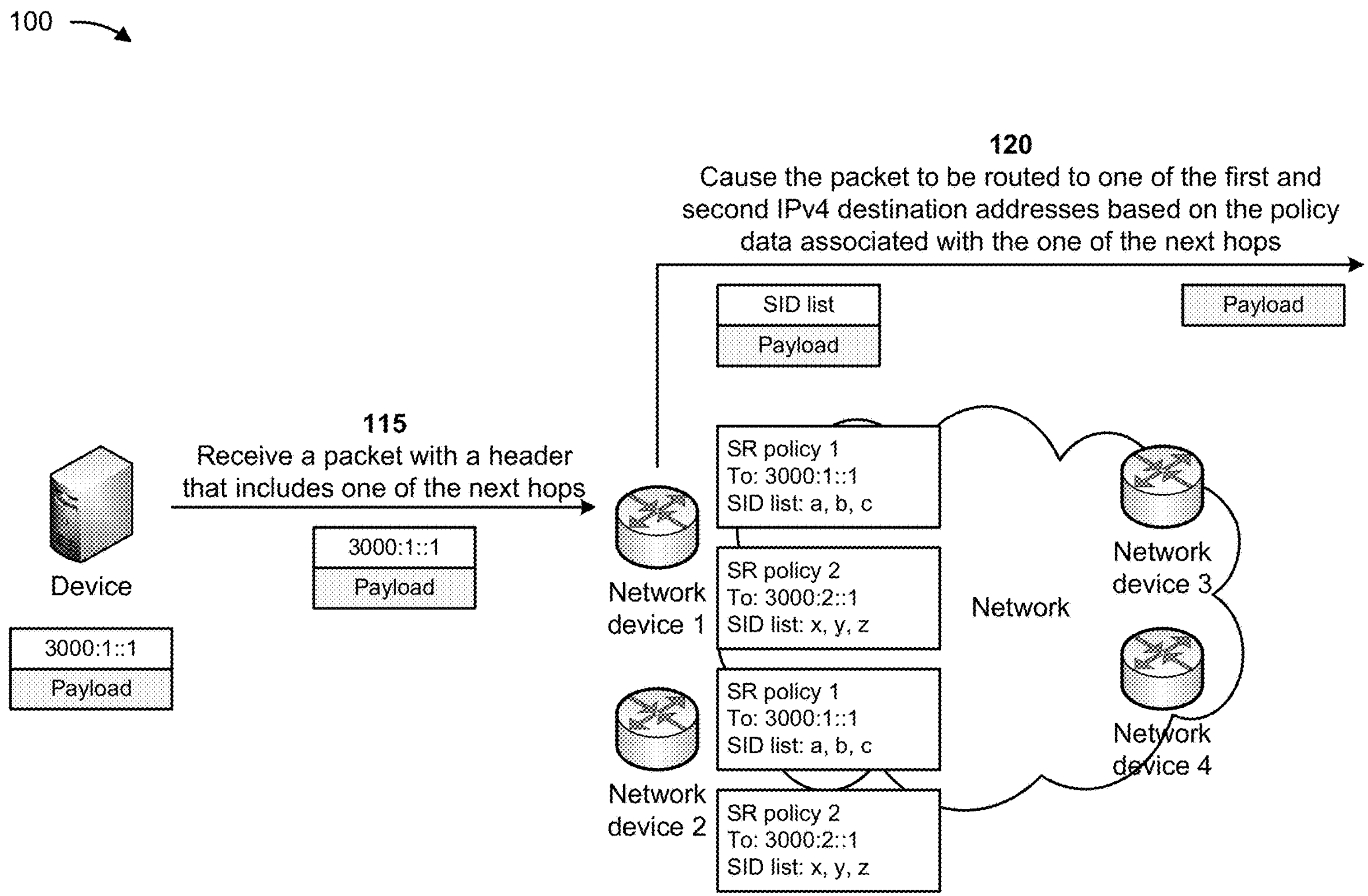
100
Device
3000:1::1
Payload
115
Receive a packet with a header that includes one of the next hops
3000:1::1
Payload
Network device 1
Network device 2
SR policy 1
To: 3000:1::1
SID list: a, b, c
SR policy 2
To: 3000:2::1
SID list: x, y, z
SR policy 1
To: 3000:1::1
SID list: a, b, c
SR policy 2
To: 3000:2::1
SID list: x, y, z
120
Cause the packet to be routed to one of the first and second IPv4 destination addresses based on the policy data associated with the one of the next hops
SID list
Payload
Payload
Network
Network device 3
Network device 4

FIG. 1B

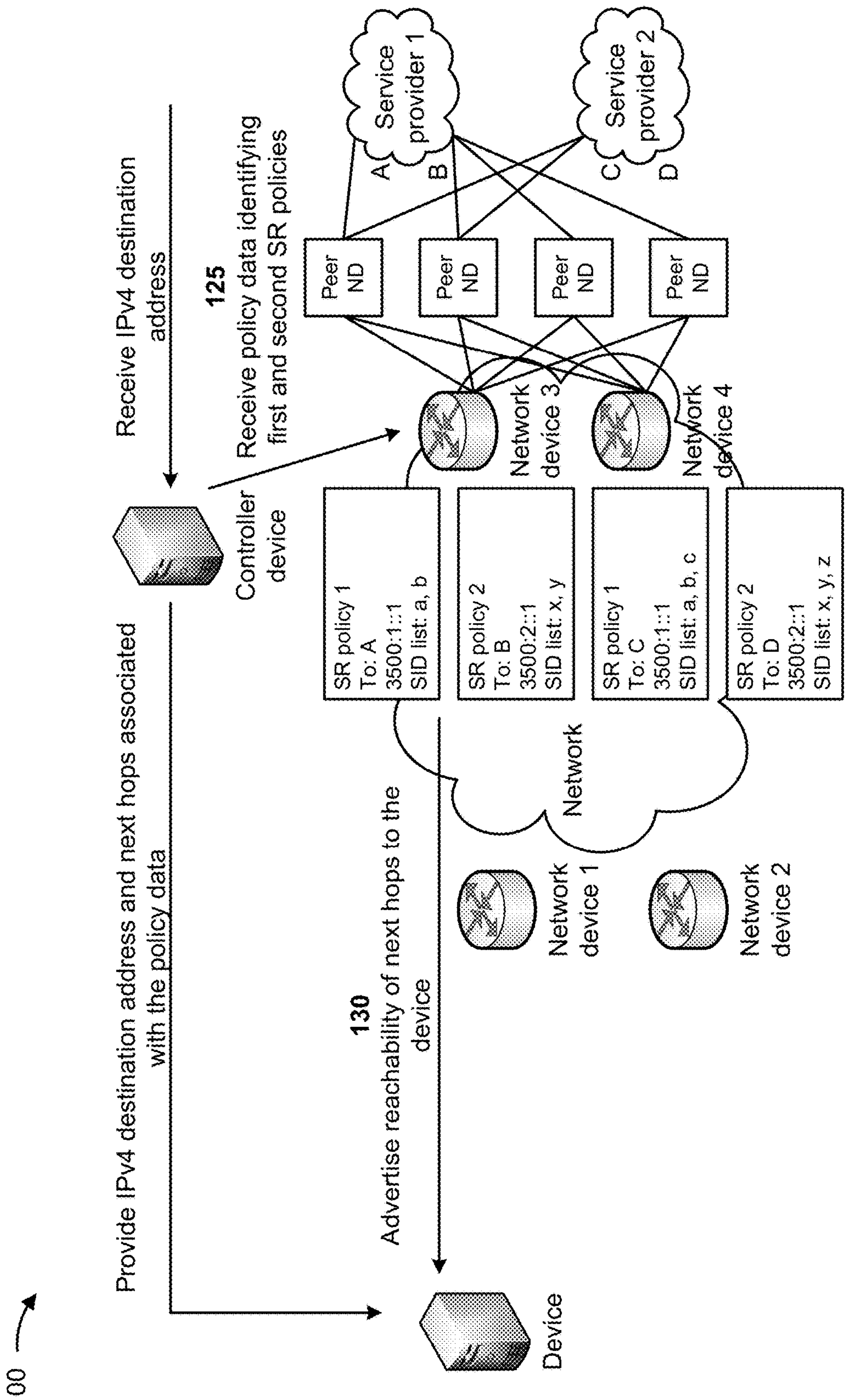
100
Receive IPv4 destination address
125
Receive policy data identifying first and second SR policies
Controller device
Provide IPv4 destination address and next hops associated with the policy data
130
Advertise reachability of next hops to the device
Device
Service provider 1
Service provider 2
A
B
C
D
Peer ND
Peer ND
Peer ND
Peer ND
Network device 3
Network device 4
Network device 1
Network device 2
Network
SR policy 1
To: A
3500:1::1
SID list: a, b
SR policy 2
To: B
3500:2::1
SID list: x, y
SR policy 1
To: C
3500:1::1
SID list: a, b, c
SR policy 2
To: D
3500:2::1
SID list: x, y, z

FIG. 1C

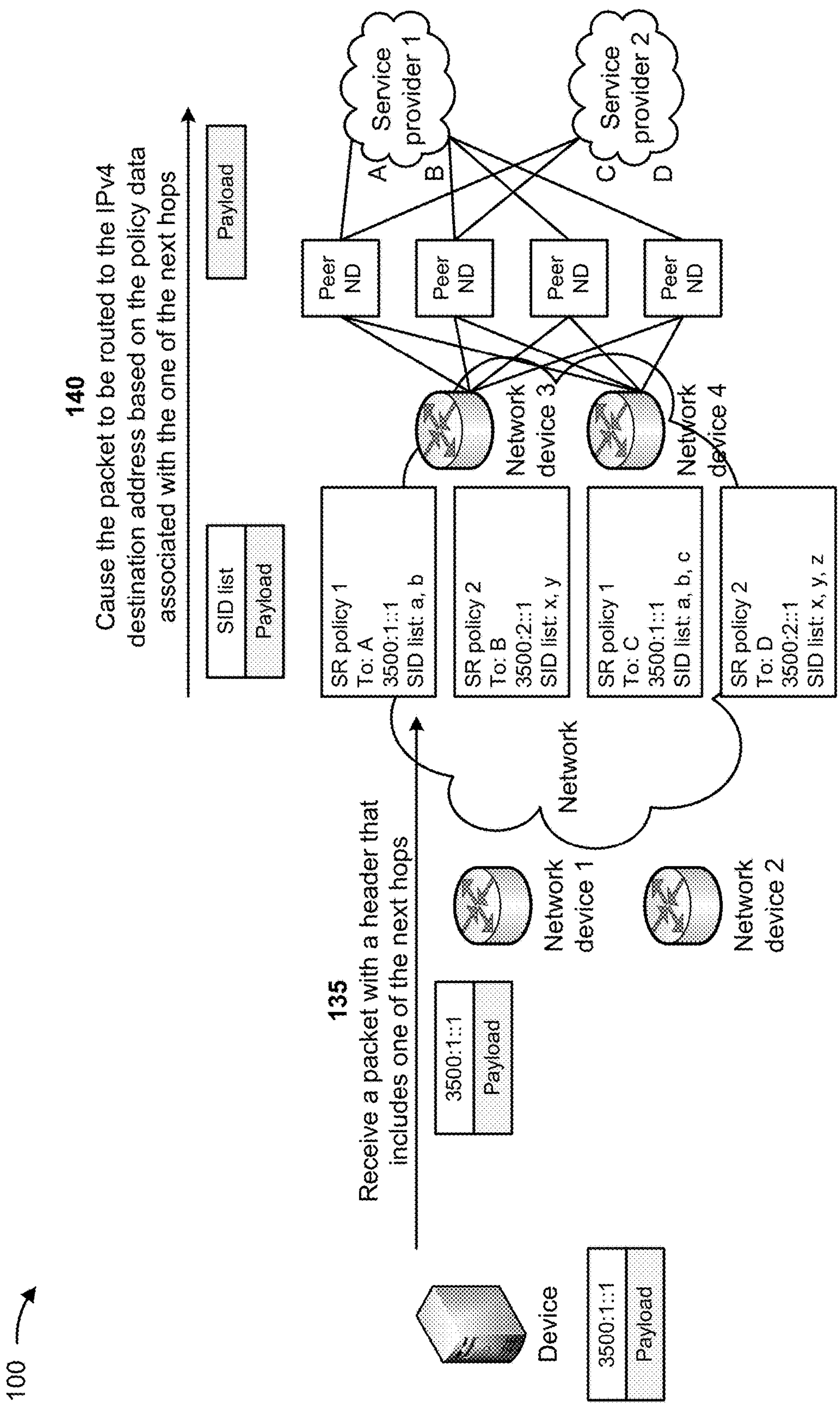
100
Device
3500:1::1
Payload
135
Receive a packet with a header that includes one of the next hops
3500:1::1
Payload
Network device 1
Network device 2
Network
SR policy 1
To: A
3500:1::1
SID list: a, b
SR policy 2
To: B
3500:2::1
SID list: x, y
SR policy 1
To: C
3500:1::1
SID list: a, b, c
SR policy 2
To: D
3500:2::1
SID list: x, y, z
Network device 3
Network device 4
Peer ND
Peer ND
Peer ND
Peer ND
A
B
C
D
Service provider 1
Service provider 2
140
Cause the packet to be routed to the IPv4 destination address based on the policy data associated with the one of the next hops
SID list
Payload
Payload

FIG. 1D

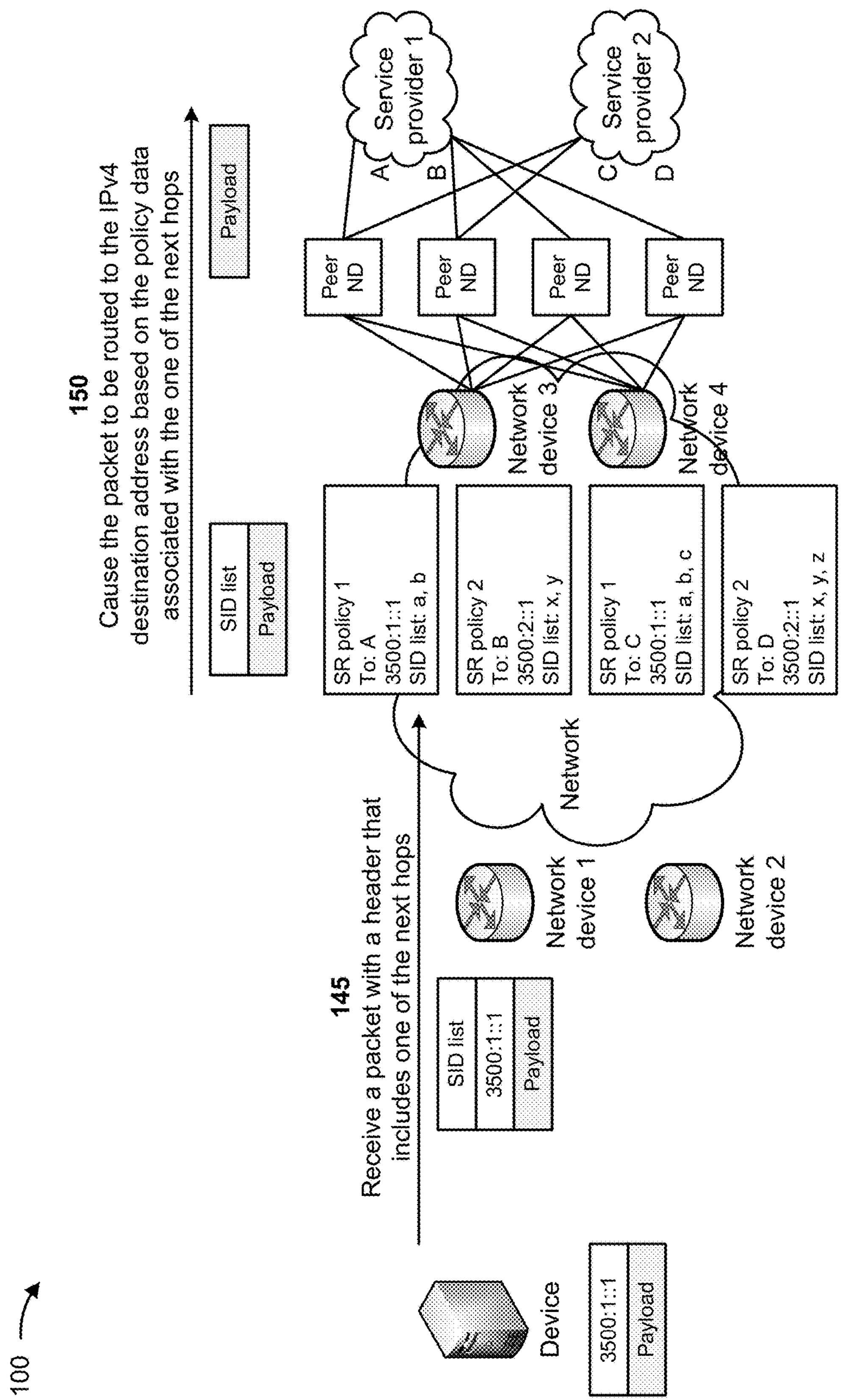
100
Device
3500:1::1
Payload
145
Receive a packet with a header that includes one of the next hops
SID list
3500:1::1
Payload
Network device 1
Network device 2
Network
SR policy 1
To: A
3500:1::1
SID list: a, b
SR policy 2
To: B
3500:2::1
SID list: x, y
SR policy 1
To: C
3500:1::1
SID list: a, b, c
SR policy 2
To: D
3500:2::1
SID list: x, y, z
Network device 3
Network device 4
Peer ND
Peer ND
Peer ND
Peer ND
A
B
C
D
Service provider 1
Service provider 2
150
Cause the packet to be routed to the IPv4 destination address based on the policy data associated with the one of the next hops
SID list
Payload
Payload

FIG. 1E

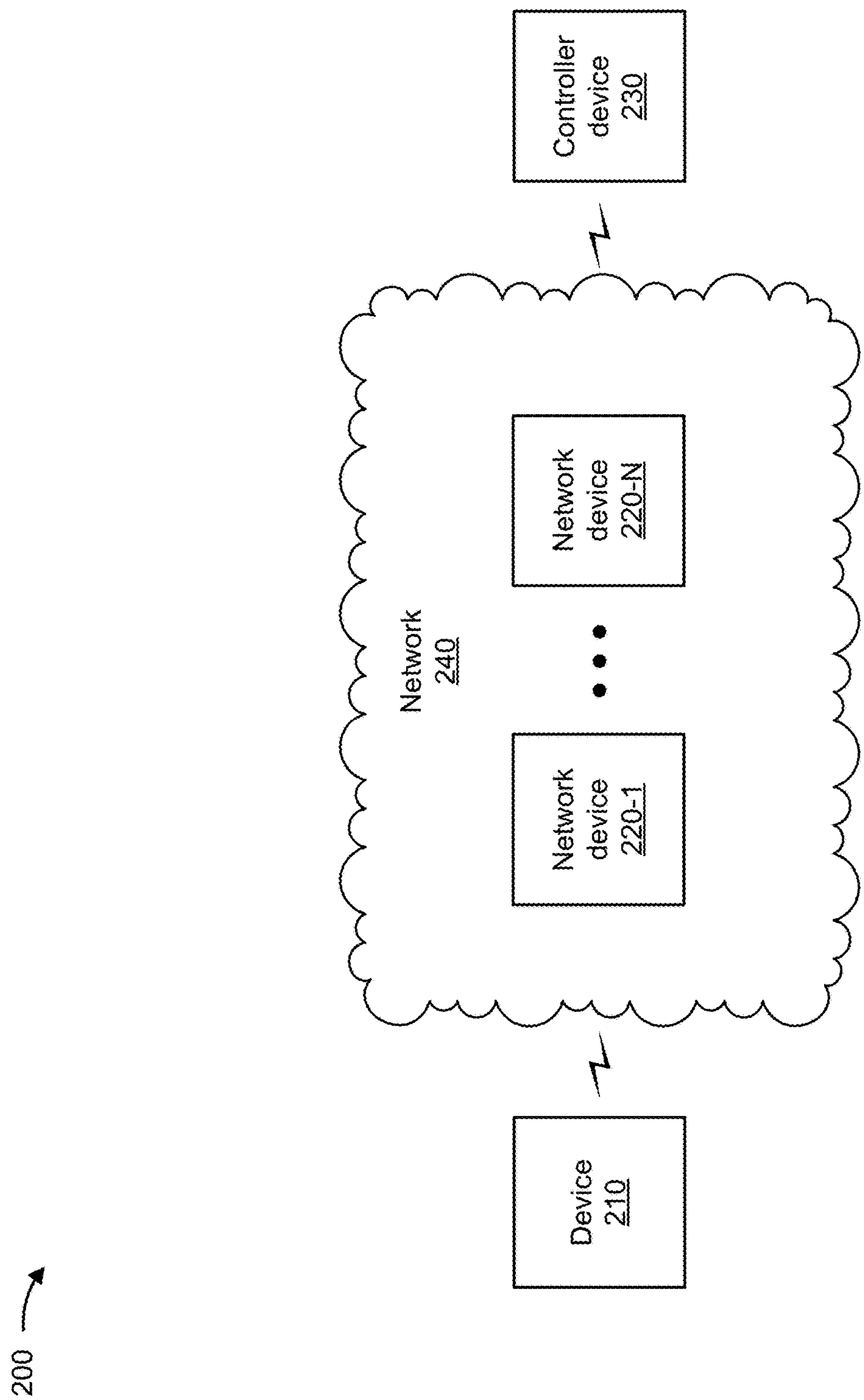
200
Device
210
Network
240
Network
device
220-1
Network
device
220-N
Controller
device
230

FIG. 2

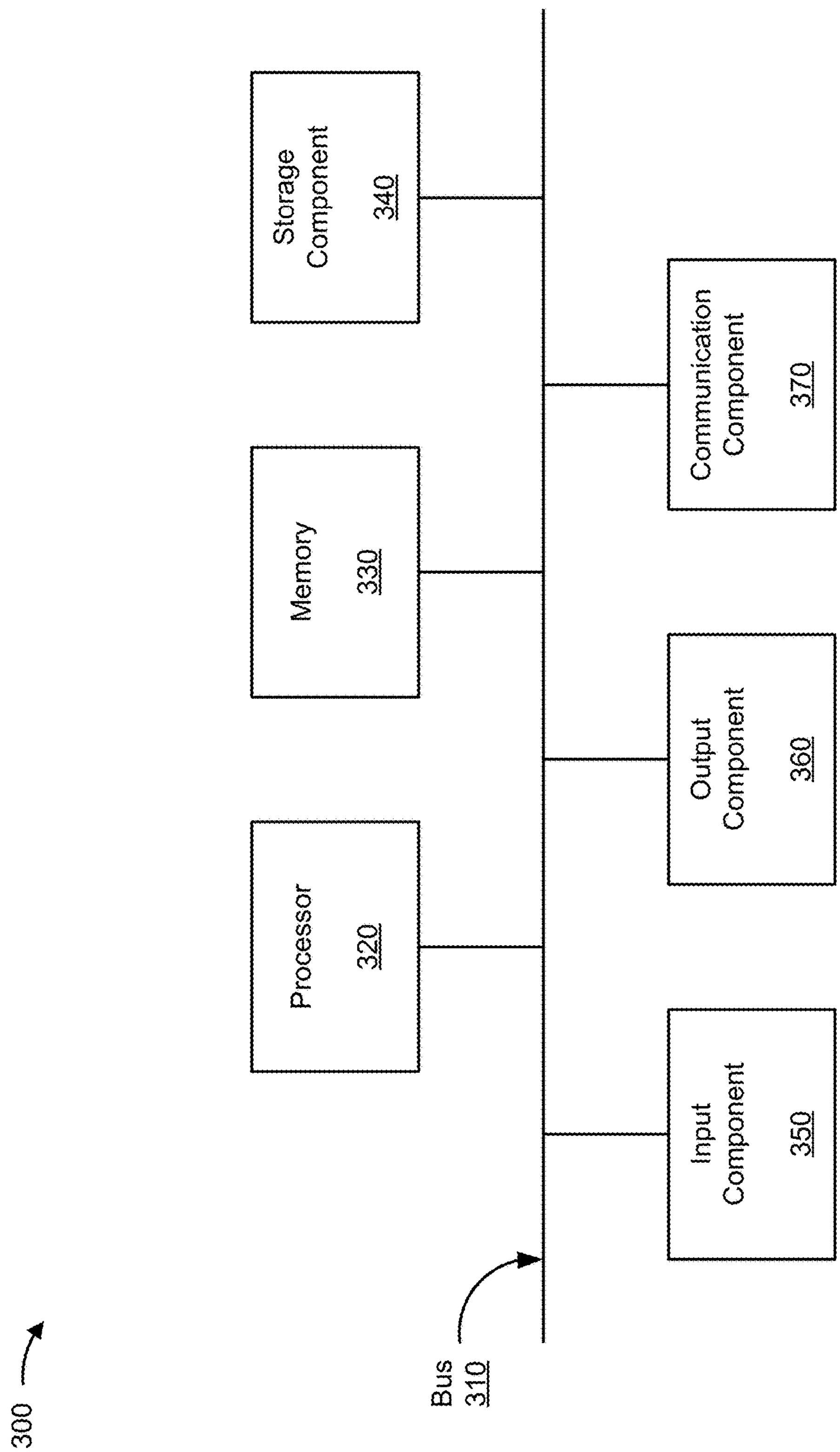
300
Bus 310
Processor 320
Memory 330
Storage Component 340
Input Component 350
Output Component 360
Communication Component 370

FIG. 3

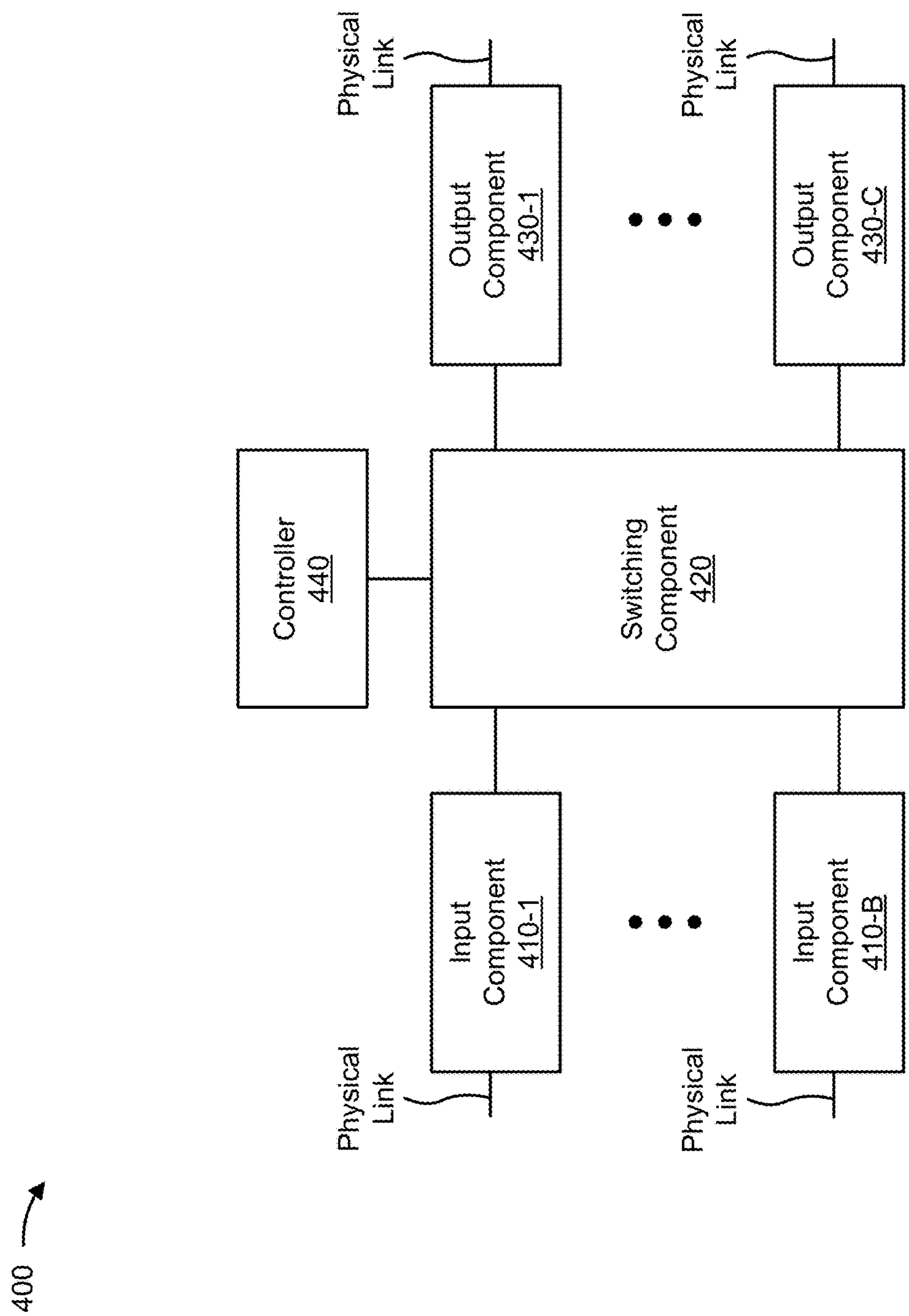
400
Physical Link
Physical Link
Physical Link
Physical Link
Input Component 410-1
Input Component 410-B
Controller 440
Switching Component 420
Output Component 430-1
Output Component 430-C

FIG. 4

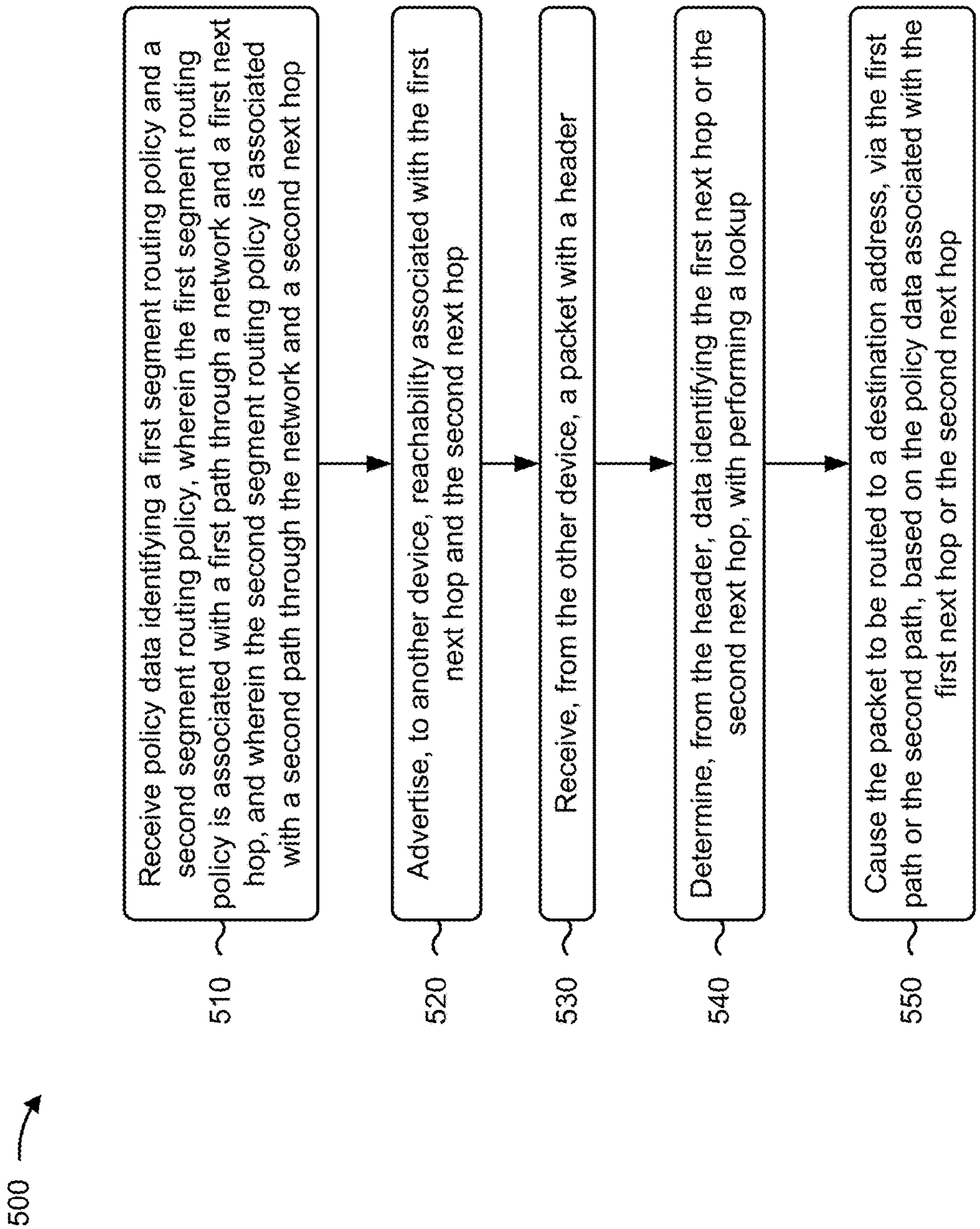
500
510
Receive policy data identifying a first segment routing policy and a second segment routing policy, wherein the first segment routing policy is associated with a first path through a network and a first next hop, and wherein the second segment routing policy is associated with a second path through the network and a second next hop
520
Advertise, to another device, reachability associated with the first next hop and the second next hop
530
Receive, from the other device, a packet with a header
540
Determine, from the header, data identifying the first next hop or the second next hop, with performing a lookup
550
Cause the packet to be routed to a destination address, via the first path or the second path, based on the policy data associated with the first next hop or the second next hop

FIG. 5

SEAMLESS SEGMENT ROUTING FOR MULTIPROTOCOL LABEL SWITCHING (MPLS) INTERWORKING

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. patent application Ser. No. 17/248,905, filed Feb. 12, 2021, which claims priority to India Patent Application No. 202041057114, entitled "SEAMLESS SEGMENT ROUTING FOR MULTIPROTOCOL LABEL SWITCHING (MPLS) INTERWORKING," filed on Dec. 30, 2020. The entire contents of which are expressly incorporated herein by reference.

BACKGROUND

Segment routing over an Internet protocol version 6 (IPv6) data plane (SRv6) is a network programming concept that enables a network to encode a network program into individual network instructions (e.g., functions) that are inserted into IPv6 packet headers.

SUMMARY

In some implementations, a method may include receiving policy data identifying a first segment routing policy and a second segment routing policy. The first segment routing policy may be associated with a first path through a network and a first next hop, and the second segment routing policy may be associated with a second path through the network and a second next hop. The method may include advertising, to another device, reachability associated with the first next hop and the second next hop, receiving, from the other device, a packet with a header. The method may include determining, from the header, data identifying the first next hop or the second next hop, with performing a lookup, and causing the packet to be routed to a destination address, via the first path or the second path, based on the policy data associated with the first next hop or the second next hop.

In some implementations, a network device may include one or more memories and one or more processors to receive policy data identifying a first segment routing policy and a second segment routing policy. The first segment routing policy may be associated with a first path through a network and a first next hop, and the second segment routing policy may be associated with a second path through the network and a second next hop. The one or more processors may advertise, to another device, reachability associated with the first next hop and the second next hop, and may receive, from the other device, a packet with a header, wherein the packet may be associated with an application of the other device. The one or more processors may determine, from the header, data identifying the plurality of next hops, without performing a lookup, and may cause the packet to be routed to a destination address, via the first path or the second path, based on the policy data associated with the first next hop or the second next hop.

In some implementations, a non-transitory computer-readable medium may store a set of instructions that includes one or more instructions that, when executed by one or more processors of a network device, cause the network device to receive policy data identifying a plurality of segment routing policies, wherein each of the plurality of segment routing policies may be associated with a corresponding path, of a plurality of paths, through a network and a corresponding next hop of a plurality of next hops. The one or more instructions may cause the network device to advertise, to another device, reachability associated with the plurality of next hops, and receive, from the other device, a packet with a header. The one or more instructions may cause the network device to determine, from the header, data identifying the first next hop or the second next hop, without performing a lookup, and cause the packet to be routed to a destination address, via one of the plurality of paths, based on the policy data associated with the one of the plurality of next hops.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1A-1**E are diagrams of an example implementation described herein.

FIG. **2** is a diagram of an example environment in which systems and/or methods described herein may be implemented.

FIGS. **3** and **4** are diagrams of example components of one or more devices of FIG. **2**.

FIG. **5** is a flowchart of an example process for seamless segment routing for multiprotocol label switching (MPLS) interworking.

DETAILED DESCRIPTION

The following detailed description of example implementations refers to the accompanying drawings. The same reference numbers in different drawings may identify the same or similar elements.

Data center environments are mostly incapable of utilizing MPLS, whereas networks associated with data centers (e.g., wide area networks) are predominantly IP/MPLS networks. Edge network devices of the networks are configured with policies that may be utilized by applications generated by the data centers. However, there may be thousands of data center applications and each application may utilize a different policy. Thus, the edge network devices must maintain information identifying the policies and relationships between the data center applications and the policies. Furthermore, information associated with service routes utilized by the edge network devices is duplicated multiple times in the edge network devices.

Wide area networks (WANs) and backbone networks include a large quantity of paths. Such networks require traffic engineering in terms of explicit paths, link constraints, bandwidth management, and/or the like. MPLS is widely deployed in such networks. Access and aggregation networks may not require significant traffic engineering. Similarly, data center environments do not require traffic engineering and may not utilize MPLS. Thus, traffic on WAN edge network devices need to be mapped to respective paths.

Thus, current solutions for policy management for data centers waste computing resources (e.g., processing resources, memory resources, communication resources, and/or the like), network resources, and/or the like associated with maintaining information identifying the policies, maintaining information identifying the relationships between the data center applications and the policies, storing such information in edge network devices, and/or the like.

Some implementations described herein relate to a network device that provides segment routing for MPLS interworking. For example, the network device may receive policy data identifying a first segment routing policy and a second segment routing policy. The first segment routing policy may be associated with a first path through a network and a first next hop, and the second segment routing policy may be associated with a second path through the network and a second next hop. The network device may advertise, to another device, reachability associated with the first next hop and the second next hop, and may receive, from the other device, a packet with a header that includes data identifying the first next hop or the second next hop. The network device may cause the packet to be routed to a destination address, via the first path or the second path, based on the policy data associated with the first next hop or the second next hop.

In this way, the network device provides segment routing for MPLS interworking. The network device may be associated with segment routing policies that define paths to be followed in a network associated with the network device, and may advertise next hops to a device (e.g., a host server device of a data center). The next hops may be associated with the paths defined by the segment routing policies. The network device may receive, from the device, a packet that includes a header with a next hop identifier, and may cause the packet to be routed to a destination address via a path associated with the next hop identifier. This, in turn, conserves computing resources, networking resources, and/or the like that would otherwise have been wasted in maintaining information identifying the policies, maintaining information identifying the relationships between the data center applications and the policies, storing such information in edge network devices, and/or the like.

FIGS. **1**A-**1**E are diagrams of an example **100** associated with providing segment routing for MPLS interworking. As shown in FIGS. **1**A-**1**E, example **100** includes a device associated with a network (e.g., a wide area network or WAN) and a controller device. The network may include multiple network devices (e.g., network device **1**, network device **2**, network device **3**, and network device **4**). The device may include a data center server that provides applications utilizing different network policies, an access network device (e.g., an access router), an egress peer network device, and/or the like. The controller device may include a server device, a cloud-based device, and/or the like that provides information to the network devices and/or the device. Each of the network devices may include a router, a gateway, a switch, a firewall, a hub, a bridge, a reverse proxy, and/or the like.

As further shown in FIG. **1**A, and by reference number **105**, a first network device (e.g., network device **1**) and/or a second network device (e.g., network device **2**) may receive, from the controller device, policy data identifying first and second segment routing (SR) policies to be implemented by the first network device and the second network device. For example, the first segment routing policy (e.g., SR policy 1) may include information identifying a first next hop network device (e.g., an address of a first edge network device, such as 3000:1::1) and a first segment identifier (SID) list identifying a first path through the network to the first edge network device (e.g., "a, b, c"). The second segment routing policy (e.g., SR policy 2) may include information identifying a second next hop network device (e.g., an address of a second edge network device, such as 3000:2::1) and a second SID list identifying a second path through the network to the second edge network device (e.g., "x, y, z"). The first network device and the second network device may store the first and second SR policies in memories associated with the first network device and the second network device.

As further shown in FIG. **1**A, and by reference number **110**, the first network device and/or the second network device may advertise reachability of the next hops (e.g., the first next hop network device and the second next hop network device) to the device. For example, the first network device and/or the second network device may advertise addresses of the next hops by providing the addresses of the next hops to the device.

As further shown in FIG. **1**A, the controller device may receive first and second destination addresses (e.g., Internet protocol version 4 (IPv4) addresses) associated with first and second destinations. In some implementations, the first and second destinations include one or more other devices that communicate with the device (e.g., a machine-to-machine communication). The first destination address may include a first border gateway protocol (BGP) IPv4 prefix (e.g., 192.1.1.1) and the second destination address may include a second BGP IPv4 prefix (e.g., 192.2.1.1). The controller device may receive the first and second destination addresses from the one or more other devices that communicate with the device.

As further shown in FIG. **1**A, the controller device may provide, to the device, the first and second destination addresses and data identifying the next hops (e.g., the first next hop network device and the second next hop network device) associated with the policy data. In this way, the device may store information identifying relationships between the policy data and applications provided by the device, rather than such information being maintained in the network devices.

As shown in FIG. **1**B, and by reference number **115**, the first network device or the second network device may receive, from the device, a packet with a header that includes data identifying one of the next hops. For example, the header of the packet may include an address of the first next hop network device (e.g., 3000:1::1). The address of the first next hop network device may be utilized by the first network device or the second network device to forward the packet along the first path in accordance with the first segment routing policy, without the first network device or the second network device having to perform a search for the first segment routing policy. In some implementations, an application of the device generates the packet with the header. The packet may be destined for one of the destination addresses (e.g., which may also be included in the header), and may include a payload associated with the application.

As further shown in FIG. **1**B, and by reference number **120**, the first network device or the second network device may cause the packet to be routed to one of the first IPv4 destination address or the second IPv4 destination address based on the policy data associated with the one of the next hops. In some implementations, the first network device or the second network device may decapsulate the header of the packet (e.g., an extra IPv6 header) and may impose an MPLS SID list without having to perform a forward information base (FIB) lookup for the inner payload of the packet. This enables high scalability since the first network device or the second network device need not store inner payload destinations in the FIB, which may include a large quantity of routes.

For example, the first network device or the second network device may analyze the header of the packet to determine that the packet is to be routed along the first path in accordance with the first segment routing policy. The first network device or the second network device may remove the header from the packet and may add a new header to the packet based on the determination. The new header may include the first SID list (e.g., "a, b, c") in accordance with the first segment routing policy and the first IPv4 destination address or the second IPv4 destination address. The packet may be routed through the network to the first IPv4 destination address or the second IPv4 destination address based on the new header. The new header may be removed prior to the packet being delivered to the first IPv4 destination address or the second IPv4 destination address, as further shown in FIG. **1**B.

As shown in FIGS. **1**C-**1**E, example **100** may further include a peer network of peer network devices (NDs) provided between the third network device (e.g., network device **3**) and the fourth network device (e.g., network device **4**) and two service provider networks (e.g., a first service provider network (e.g., service provider 1) and a second service provider network (e.g., service provider 2)). Each of the peer network devices includes one or more devices capable of receiving and/or providing network traffic, such as a router, a gateway, a switch, a firewall, a hub, a bridge, a reverse proxy, and/or the like. Each of the service provider networks may include one or more networks that provide services (e.g., applications) from the device to one or more users (e.g., user A, user B, user C, user D, and/or the like). Thus, communications between the device and the service provider networks may be referred to as machine-to-user communications.

As further shown in FIG. **1**C, and by reference number **125**, the third network device may receive, from the controller device, policy data identifying first and second SR policies to be implemented by the third network device. For example, the first segment routing policy (e.g., SR policy 1) may include information identifying a first next hop network device (e.g., an address of a first edge network device, such as 3500:1::1) and a first SID list identifying a first path through the network to the first edge network device (e.g., "a, b") and user A. The second segment routing policy (e.g., SR policy 2) may include information identifying a second next hop network device (e.g., an address of a second edge network device, such as 3500:2::1) and a second SID list identifying a second path through the network to the second edge network device (e.g., "x, y") and user B. The third network device may store the first and second SR policies in memory associated with the third network device.

Alternatively, or additionally, the fourth network device may receive, from the controller device, policy data identifying first and second SR policies to be implemented by the fourth network device. For example, the first segment routing policy (e.g., SR policy 1) may include information identifying the first next hop network device (e.g., the address of the first edge network device, such as 3500:1::1) and a third SID list identifying a third path through the network to the first edge network device (e.g., "a, b, c") and user C. The second segment routing policy (e.g., SR policy 2) may include information identifying the second next hop network device (e.g., an address of a second edge network device, such as 3500:2::1) and a fourth SID list identifying a fourth path through the network to the second edge network device (e.g., "x, y, z") and user D. The fourth network device may store the first and second SR policies in memory associated with the fourth network device.

As further shown in FIG. **1**C, and by reference number **130**, the third network device and/or the fourth network device may advertise reachability of the next hops (e.g., the first next hop network device and the second next hop network device) to the device. For example, the third network device and/or the fourth network device may advertise addresses of the next hops by providing the addresses of the next hops to the device. The reachability of the next hops may be advertised via an internal border gateway protocol (iBGP), BGP dynamic segment routing traffic engineering (BGP-SR-TE) protocol, a BGP classful transport (BGP-CT) protocol, an external BGP (eBGP) protocol, a BGP labeled unicast (BGP-LU) protocol, and/or the like.

As further shown in FIG. **1**C, the controller device may receive a destination address (e.g., an IPv4 destination address) associated with a destination (e.g., user A, user B, user C, or user D). For example, the destination address may include a BGP IPv4 prefix (e.g., 10/8) associated with the first service provider network, a BGP IPv4 prefix associated with the second service provider network, and/or the like. The controller device may receive the destination address from the first service provider network or the second service provider network.

As further shown in FIG. **1**C, the controller device may provide, to the device, the IPv4 destination address and data identifying the next hops (e.g., the first next hop network device and the second next hop network device) associated with the policy data. In this way, the device may store information identifying relationships between the policy data and applications provided by the device, rather than such information being maintained in the network devices.

As shown in FIG. **1**D, and by reference number **135**, the third network device or the fourth network device may receive, from the device, a packet with a header that includes data identifying one of the next hops. For example, the header of the packet may include an address of the first next hop network device (e.g., 3500:1::1). The address of the first next hop network device may be utilized by the third network device or the fourth network device to forward the packet along the first path in accordance with the first segment routing policy, without having to perform a search for the first segment routing policy. In some implementations, an application of the device generates the packet with the header. The packet may be destined for the destination address (e.g., which may also be included in the header), and may include a payload associated with the application. In some implementations, the packet may be forwarded through the network via best effort forwarding. Best effort forwarding may not provide any guarantee that traffic is delivered or that delivery of the traffic satisfies any quality of service.

As further shown in FIG. **1**D, and by reference number **140**, the third network device or the fourth network device may cause the packet to be routed to the IPv4 destination address based on the policy data associated with the one of the next hops. In some implementations, the third network device or the fourth network device may decapsulate the header of the packet and may impose an MPLS SID list without having to perform a FIB lookup for the inner payload of the packet. This enables high scalability since the third network device or the fourth network device need not store inner payload destinations in the FIB, which may include a large quantity of routes.

For example, the third network device or the fourth network device may analyze the header of the packet to determine that the packet is to be routed along the first path in accordance with the first segment routing policy. The third network device or the fourth network device may remove the header from the packet and may add a new header to the packet based on the determination. The new header may include the first SID list (e.g., "a, b") in accordance with the first segment routing policy and the IPv4 destination address (e.g., an address of user A). The packet may be routed through the network and the peer network to the IPv4 destination address based on the new header. The new header may be removed prior to the packet being delivered to the IPv4 destination address, as further shown in FIG. **1**D.

In some implementations, as shown in FIG. **1**E, packets may be forwarded through the network via BGP dynamic segment routing traffic engineering. BGP dynamic segment routing traffic engineering (BGP-SR-TE) provides capabilities to steer traffic through the network without any state creation and maintenance (e.g., stateless). As further shown in FIG. **1**E, and by reference number **145**, the third network device or the fourth network device may receive, from the device, a packet with a header that includes a SID list and data identifying one of the next hops. For example, the header of the packet may include an address of the first next hop network device (e.g., 3500:1::1) and the first SID list or the third SID list, as described above. The address of the first next hop network device may be utilized by the third network device or the fourth network device to forward the packet along the first path in accordance with the first segment routing policy, without having to perform a search for the first segment routing policy. In some implementations, an application of the device generates the packet with the header. The packet may be destined for the destination address (e.g., which may also be included in the header), and may include a payload associated with the application.

As further shown in FIG. **1**E, and by reference number **150**, the third network device or the fourth network device may cause the packet to be routed to the IPv4 destination address based on the policy data associated with the one of the next hops. In some implementations, the third network device or the fourth network device may decapsulate the header of the packet and may impose an MPLS SID list without having to perform a FIB lookup for the inner payload of the packet. This enables high scalability since the third network device or the fourth network device need not store inner payload destinations in the FIB, which may include a large quantity of routes.

For example, the third network device or the fourth network device may analyze the header of the packet to determine that the packet is to be routed along the first path in accordance with the first segment routing policy. The third network device or the fourth network device may remove the header from the packet and may add a new header to the packet based on the determination. For example, the new header may include the third SID list (e.g., "a, b, c") in accordance with the first segment routing policy and the IPv4 destination address (e.g., an address of user C). The packet may be routed through the network and the peer network to the IPv4 destination address based on the new header. The new header may be removed prior to the packet being delivered to the IPv4 destination address, as further shown in FIG. **1**E.

In this way, the network device provides segment routing for MPLS interworking. The network device may be associated with segment routing policies that define paths to be followed in a network associated with the network device, and may advertise next hops to a device (e.g., of a data center). The next hops may be associated with the paths defined by the segment routing policies. The network device may receive, from the device, a packet that includes a header with a next hop identifier, and may cause the packet to be routed to a destination address via a path associated with the next hop identifier. This, in turn, conserves computing resources, networking resources, and/or the like that would otherwise have been wasted in maintaining information identifying the policies, maintaining information identifying the relationships between the data center applications and the policies, storing such information in edge network devices, and/or the like.

As indicated above, FIGS. **1**A-**1**E are provided as an example. Other examples may differ from what is described with regard to FIGS. **1**A-**1**E. The number and arrangement of devices shown in FIGS. **1**A-**1**E are provided as an example. In practice, there may be additional devices, fewer devices, different devices, or differently arranged devices than those shown in FIGS. **1**A-**1**E. Furthermore, two or more devices shown in FIGS. **1**A-**1**E may be implemented within a single device, or a single device shown in FIGS. **1**A-**1**E may be implemented as multiple, distributed devices. Additionally, or alternatively, a set of devices (e.g., one or more devices) shown in FIGS. **1**A-**1**E may perform one or more functions described as being performed by another set of devices shown in FIGS. **1**A-**1**E.

FIG. **2** is a diagram of an example environment **200** in which systems and/or methods described herein may be implemented. As shown in FIG. **2**, environment **200** may include a device **210**, a group of network devices **220** (shown as network device **220-1** through network device **220**-N), a controller device **230**, and a network **240**. Devices of environment **200** may interconnect via wired connections, wireless connections, or a combination of wired and wireless connections.

Device **210** includes one or more devices capable of receiving, generating, storing, processing, providing, and/or routing information, as described elsewhere herein. Device **210** may include a communication device and/or a computing device. For example, device **210** may include a server, such as an application server, a client server, a web server, a database server, a host server, a proxy server, a virtual server (e.g., executing on computing hardware), a data center server, an access network device, a peer egress network device, or a server in a cloud computing system. In some implementations, device **210** includes computing hardware used in a cloud computing environment.

Network device **220** includes one or more devices capable of receiving, processing, storing, routing, and/or providing traffic (e.g., a payload packet, an application, etc.) in a manner described herein. For example, network device **220** may include a router, such as a label switching router (LSR), a label edge router (LER), an ingress router, an egress router, a provider router (e.g., a provider edge router, a provider core router, etc., a virtual router, and/or the like). Additionally, or alternatively, network device **220** may include a gateway, a switch, a firewall, a hub, a bridge, a reverse proxy, a server (e.g., a proxy server, a cloud server, a data center server, etc.), a load balancer, and/or a similar device.

In some implementations, network device **220** may be a physical device implemented within a housing, such as a chassis. In some implementations, network device **220** may be a virtual device implemented by one or more computer devices of a cloud computing environment or a data center. In some implementations, network device **220** may be an edge network device in network **240**. In some implementations, network device **220** may be an intermediary network device in network **240** (i.e., a network device between two or more edge network devices).

Controller device **230** includes one or more devices capable of receiving, generating, storing, processing, providing, and/or routing information, as described elsewhere herein. Controller device **230** may include a communication device and/or a computing device. For example, controller device **230** may include a server, such as an application server, a client server, a web server, a database server, a host server, a proxy server, a virtual server (e.g., executing on computing hardware), or a server in a cloud computing system. In some implementations, controller device **230** includes computing hardware used in a cloud computing environment.

Network **240** includes one or more wired and/or wireless networks. For example, network **240** may include a cellular network (e.g., a fifth generation (5G) network, a fourth generation (4G) network, such as a long-term evolution (LTE) network, a third generation (3G) network, a code division multiple access (CDMA) network, a public land mobile network (PLMN), a local area network (LAN), a wide area network (WAN), a metropolitan area network (MAN), a telephone network (e.g., the Public Switched Telephone Network (PSTN)), a private network, an ad hoc network, an intranet, the Internet, a fiber optic-based network, a cloud computing network, or the like, and/or a combination of these or other types of networks.

The number and arrangement of devices and networks shown in FIG. **2** are provided as one or more examples. In practice, there may be additional devices and/or networks, fewer devices and/or networks, different devices and/or networks, or differently arranged devices and/or networks than those shown in FIG. **2**. Furthermore, two or more devices shown in FIG. **2** may be implemented within a single device, or a single device shown in FIG. **2** may be implemented as multiple, distributed devices. Additionally, or alternatively, a set of devices (e.g., one or more devices) of environment **200** may perform one or more functions described as being performed by another set of devices of environment **200**.

FIG. **3** is a diagram of example components of a device **300**, which may correspond to device **210**, network device **220**, and/or controller device **230**. In some implementations, device **210**, network device **220**, and/or controller device **230** may include one or more devices **300** and/or one or more components of device **300**. As shown in FIG. **3**, device **300** may include a bus **310**, a processor **320**, a memory **330**, a storage component **340**, an input component **350**, an output component **360**, and a communication component **370**.

Bus **310** includes a component that enables wired and/or wireless communication among the components of device **300**. Processor **320** includes a central processing unit, a graphics processing unit, a microprocessor, a controller, a microcontroller, a digital signal processor, a field-programmable gate array, an application-specific integrated circuit, and/or another type of processing component. Processor **320** is implemented in hardware, firmware, or a combination of hardware and software. In some implementations, processor **320** includes one or more processors capable of being programmed to perform a function. Memory **330** includes a random access memory, a read only memory, and/or another type of memory (e.g., a flash memory, a magnetic memory, and/or an optical memory).

Storage component **340** stores information and/or software related to the operation of device **300**. For example, storage component **340** may include a hard disk drive, a magnetic disk drive, an optical disk drive, a solid-state disk drive, a compact disc, a digital versatile disc, and/or another type of non-transitory computer-readable medium. Input component **350** enables device **300** to receive input, such as user input and/or sensed inputs. For example, input component **350** may include a touch screen, a keyboard, a keypad, a mouse, a button, a microphone, a switch, a sensor, a global positioning system component, an accelerometer, a gyroscope, and/or an actuator. Output component **360** enables device **300** to provide output, such as via a display, a speaker, and/or one or more light-emitting diodes. Communication component **370** enables device **300** to communicate with other devices, such as via a wired connection and/or a wireless connection. For example, communication component **370** may include a receiver, a transmitter, a transceiver, a modem, a network interface card, and/or an antenna.

Device **300** may perform one or more processes described herein. For example, a non-transitory computer-readable medium (e.g., memory **330** and/or storage component **340**) may store a set of instructions (e.g., one or more instructions, code, software code, and/or program code) for execution by processor **320**. Processor **320** may execute the set of instructions to perform one or more processes described herein. In some implementations, execution of the set of instructions, by one or more processors **320**, causes the one or more processors **320** and/or the device **300** to perform one or more processes described herein. In some implementations, hardwired circuitry may be used instead of or in combination with the instructions to perform one or more processes described herein. Thus, implementations described herein are not limited to any specific combination of hardware circuitry and software.

The number and arrangement of components shown in FIG. **3** are provided as an example. Device **300** may include additional components, fewer components, different components, or differently arranged components than those shown in FIG. **3**. Additionally, or alternatively, a set of components (e.g., one or more components) of device **300** may perform one or more functions described as being performed by another set of components of device **300**.

FIG. **4** is a diagram of example components of a device **400**. Device **400** may correspond to network device **220**. In some implementations, network device **220** may include one or more devices **400** and/or one or more components of device **400**. As shown in FIG. **4**, device **400** may include one or more input components **410-1** through **410**-B (B≥1) (hereinafter referred to collectively as input components **410**, and individually as input component **410**), a switching component **420**, one or more output components **430-1** through **430**-C (C≥1) (hereinafter referred to collectively as output components **430**, and individually as output component **430**), and a controller **440**.

Input component **410** may be one or more points of attachment for physical links and may be one or more points of entry for incoming traffic, such as packets. Input component **410** may process incoming traffic, such as by performing data link layer encapsulation or decapsulation. In some implementations, input component **410** may transmit and/or receive packets. In some implementations, input component **410** may include an input line card that includes one or more packet processing components (e.g., in the form of integrated circuits), such as one or more interface cards (IFCs), packet forwarding components, line card controller components, input ports, processors, memories, and/or input queues. In some implementations, device **400** may include one or more input components **410**.

Switching component **420** may interconnect input components **410** with output components **430**. In some implementations, switching component **420** may be implemented via one or more crossbars, via busses, and/or with shared memories. The shared memories may act as temporary buffers to store packets from input components **410** before the packets are eventually scheduled for delivery to output components **430**. In some implementations, switching component **420** may enable input components **410**, output components **430**, and/or controller **440** to communicate with one another.

Output component **430** may store packets and may schedule packets for transmission on output physical links. Output component **430** may support data link layer encapsulation or decapsulation, and/or a variety of higher-level protocols. In some implementations, output component **430** may transmit packets and/or receive packets. In some implementations, output component **430** may include an output line card that includes one or more packet processing components (e.g., in the form of integrated circuits), such as one or more IFCs, packet forwarding components, line card controller components, output ports, processors, memories, and/or output queues. In some implementations, device **400** may include one or more output components **430**. In some implementations, input component **410** and output component **430** may be implemented by the same set of components (e.g., and input/output component may be a combination of input component **410** and output component **430**).

Controller **440** includes a processor in the form of, for example, a CPU, a GPU, an APU, a microprocessor, a microcontroller, a DSP, an FPGA, an ASIC, and/or another type of processor. The processor is implemented in hardware, firmware, or a combination of hardware and software. In some implementations, controller **440** may include one or more processors that can be programmed to perform a function.

In some implementations, controller **440** may include a RAM, a ROM, and/or another type of dynamic or static storage device (e.g., a flash memory, a magnetic memory, an optical memory, etc.) that stores information and/or instructions for use by controller **440**.

In some implementations, controller **440** may communicate with other devices, networks, and/or systems connected to device **400** to exchange information regarding network topology. Controller **440** may create routing tables based on the network topology information, may create forwarding tables based on the routing tables, and may forward the forwarding tables to input components **410** and/or output components **430**. Input components **410** and/or output components **430** may use the forwarding tables to perform route lookups for incoming and/or outgoing packets.

Controller **440** may perform one or more processes described herein. Controller **440** may perform these processes in response to executing software instructions stored by a non-transitory computer-readable medium. A computer-readable medium is defined herein as a non-transitory memory device. A memory device includes memory space within a single physical storage device or memory space spread across multiple physical storage devices.

Software instructions may be read into a memory and/or storage component associated with controller **440** from another computer-readable medium or from another device via a communication interface. When executed, software instructions stored in a memory and/or storage component associated with controller **440** may cause controller **440** to perform one or more processes described herein. Additionally, or alternatively, hardwired circuitry may be used in place of or in combination with software instructions to perform one or more processes described herein. Thus, implementations described herein are not limited to any specific combination of hardware circuitry and software.

The number and arrangement of components shown in FIG. **4** are provided as an example. In practice, device **400** may include additional components, fewer components, different components, or differently arranged components than those shown in FIG. **4**. Additionally, or alternatively, a set of components (e.g., one or more components) of device **400** may perform one or more functions described as being performed by another set of components of device **400**.

FIG. **5** is a flowchart of an example process **500** for providing segment routing for MPLS interworking. In some implementations, one or more process blocks of FIG. **5** may be performed by a device (e.g., network device **220**). In some implementations, one or more process blocks of FIG. **5** may be performed by another device or a group of devices separate from or including the device, such as a device (e.g., device **210**) and/or a controller device (e.g., controller device **230**). Additionally, or alternatively, one or more process blocks of FIG. **5** may be performed by one or more components of device **400**, such as processor **320**, memory **330**, storage component **340**, input component **350**, output component **360**, and/or communication component **370**. Additionally, or alternatively, one or more process blocks of FIG. **5** may be performed by one or more components of device **400**, such as input component **410**, switching component **420**, output component **430**, and/or controller **440**.

As shown in FIG. **5**, process **500** may include receiving policy data identifying a first segment routing policy and a second segment routing policy, wherein the first segment routing policy is associated with a first path through a network and a first next hop, and wherein the second segment routing policy is associated with a second path through the network and a second next hop (block **510**). For example, the network device may receive policy data identifying a first segment routing policy and a second segment routing policy, as described above. In some implementations, the first segment routing policy is associated with a first path through a network and a first next hop. In some implementations, the second segment routing policy is associated with a second path through the network and a second next hop.

As further shown in FIG. **5**, process **500** may include advertising, to another device, reachability associated with the first next hop and the second next hop (block **520**). For example, the network device may advertise, to another device, reachability associated with the first next hop and the second next hop, as described above.

As further shown in FIG. **5**, process **500** may include receiving, from the other device, a packet with a header (block **530**). For example, the network device may receive, from the other device, a packet with a header, as described above.

As further shown in FIG. **5**, process **500** may include determining, from the header, data identifying the first next hop or the second next hop, with performing a lookup (block **540**). For example, the network device may determine, from the header, data identifying the first next hop or the second next hop, with performing a lookup, as described above.

As further shown in FIG. **5**, process **500** may include causing the packet to be routed to a destination address, via the first path or the second path, based on the policy data associated with the first next hop or the second next hop (block **550**). For example, the network device may cause the packet to be routed to a destination address, via the first path or the second path, based on the policy data associated with the first next hop or the second next hop, as described above.

Process **500** may include additional implementations, such as any single implementation or any combination of implementations described below and/or in connection with one or more other processes described elsewhere herein.

In a first implementation, the first segment policy includes an address of the first next hop and a first segment identifier list that identifies the first path, and the second segment policy includes an address of the second next hop and a second segment identifier list that identifies the second path.

In a second implementation, alone or in combination with the first implementation, the address of the first next hop and the address of the second next hop are each an Internet protocol version 6 address.

In a third implementation, alone or in combination with one or more of the first and second implementations, the destination address includes an Internet protocol version 4 prefix.

In a fourth implementation, alone or in combination with one or more of the first through third implementations, process **500** includes removing the header from the packet, and adding a new header to the packet, wherein the new header includes one of a first segment identifier list that identifies the first path or a second segment identifier list that identifies the second path.

In a fifth implementation, alone or in combination with one or more of the first through fourth implementations, causing the packet to be routed to the destination address, via the first path or the second path, based on the policy data associated with the first next hop or the second next hop includes removing the header from the packet; adding a new header to the packet, wherein the new header includes one of a first segment identifier list that identifies the first path or a second segment identifier list that identifies the second path; and causing the packet to be routed to the destination address, via the first path or the second path, based on the first segment identifier list or the second segment identifier list.

In a sixth implementation, alone or in combination with one or more of the first through fifth implementations, the packet is associated with an application of the other device.

In a seventh implementation, alone or in combination with one or more of the first through sixth implementations, the destination address is associated with a host server device.

In an eighth implementation, alone or in combination with one or more of the first through seventh implementations, advertising the reachability associated with the first next hop and the second next hop includes advertising, to the other device, the reachability associated with the first next hop and the second next hop via an internal border gateway protocol.

In a ninth implementation, alone or in combination with one or more of the first through eighth implementations, when the destination address is associated with a service provider network, process **500** includes removing the header from the packet, and adding a new header to the packet, wherein the new header includes an egress peer engineering segment identifier list that identifies a path to the service provider network.

In a tenth implementation, alone or in combination with one or more of the first through ninth implementations, when the destination address is associated with a service provider network, advertising the reachability associated with the first next hop and the second next hop includes advertising, to the other device, the reachability associated with the first next hop and the second next hop via dynamic segment routing traffic engineering.

In an eleventh implementation, alone or in combination with one or more of the first through tenth implementations, when the destination address is associated with a service provider network and the header includes a segment identifier list, process **500** includes removing the header from the packet, and adding a new header to the packet, wherein the new header includes an egress peer engineering segment identifier list that identifies a path to the service provider network.

In a twelfth implementation, alone or in combination with one or more of the first through eleventh implementations, the network device is an edge network device of the network, and the network is a wide area network.

Although FIG. **5** shows example blocks of process **500**, in some implementations, process **500** may include additional blocks, fewer blocks, different blocks, or differently arranged blocks than those depicted in FIG. **5**. Additionally, or alternatively, two or more of the blocks of process **500** may be performed in parallel.

The foregoing disclosure provides illustration and description, but is not intended to be exhaustive or to limit the implementations to the precise form disclosed. Modifications may be made in light of the above disclosure or may be acquired from practice of the implementations.

As used herein, the term "component" is intended to be broadly construed as hardware, firmware, or a combination of hardware and software. It will be apparent that systems and/or methods described herein may be implemented in different forms of hardware, firmware, and/or a combination of hardware and software. The actual specialized control hardware or software code used to implement these systems and/or methods is not limiting of the implementations. Thus, the operation and behavior of the systems and/or methods are described herein without reference to specific software code—it being understood that software and hardware can be used to implement the systems and/or methods based on the description herein.

Although particular combinations of features are recited in the claims and/or disclosed in the specification, these combinations are not intended to limit the disclosure of various implementations. In fact, many of these features may be combined in ways not specifically recited in the claims and/or disclosed in the specification. Although each dependent claim listed below may directly depend on only one claim, the disclosure of various implementations includes each dependent claim in combination with every other claim in the claim set.

No element, act, or instruction used herein should be construed as critical or essential unless explicitly described as such. Also, as used herein, the articles "a" and "an" are intended to include one or more items, and may be used interchangeably with "one or more." Further, as used herein, the article "the" is intended to include one or more items referenced in connection with the article "the" and may be used interchangeably with "the one or more." Furthermore, as used herein, the term "set" is intended to include one or more items (e.g., related items, unrelated items, a combination of related and unrelated items, and/or the like), and may be used interchangeably with "one or more." Where only one item is intended, the phrase "only one" or similar language is used. Also, as used herein, the terms "has," "have," "having," or the like are intended to be open-ended terms. Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise. Also, as used herein, the term "or" is intended to be inclusive when used in a series and may be used interchangeably with "and/or," unless explicitly stated otherwise (e.g., if used in combination with "either" or "only one of").

What is claimed is:

1. A method, comprising:

providing, by a first device and to a second device, information associated with reachability related to at least one next hop;

receiving, by the first device and from the second device, a packet including information associated with a first next hop of the at least one next hop;

decapsulating, by the first device, a header of the packet;

determining, by the first device, based on decapsulating the header of the packet, and based on information associated with the first next hop, that the packet is to be routed based on a particular segment routing policy, of one or more segment routing policies associated with the first device;

removing, by the first device, the header of the packet;

adding, by the first device, without performing a lookup process, and based on determining that the packet is to be routed based on the particular segment routing policy, a new header to the packet,

wherein the new header includes at least one of a first segment identifier list that identifies a first path associated with the first next hop or a second segment identifier list that identifies a second path associated with a second next hop of the at least one next hop, and

wherein the new header further includes a first destination address associated with the first segment identifier list or a second destination address associated with the second segment identifier list; and

causing, by the first device and based on the new header, the packet to be routed via a particular path associated with the particular segment routing policy.

2. The method of claim **1**, further comprising:

receiving policy data identifying the one or more segment routing policies, including the particular segment routing policy, that are associated with particular paths that include respective next hops.

3. The method of claim **1**, wherein the particular segment routing policy identifies a particular next hop and a particular segment identifier list that identifies the particular path.

4. The method of claim **1**, wherein the header further includes data identifying the second next hop,

wherein data identifying the first next hop and the second next hop is included in the header based on advertising a reachability associated with the first next hop and the second next hop, and

wherein the method further comprises:

determining routing from data identified in the first next hop and the second next hop.

5. The method of claim **1**, wherein the first segment identifier list is associated with the particular segment routing policy.

6. The method of claim **1**, wherein the header that is decapsulated is associated with an extra Internet protocol version 6 (IPv6) header.

7. The method of claim **1**, wherein the packet is associated with an application of the second device.

8. A first device, comprising:

one or more memories; and

one or more processors to:

provide, to a second device, information associated with reachability related to at least one next hop;

receive, from the second device, a packet including information associated with a first next hop of the at least one next hop;

decapsulate a header of the packet;

determine, based on decapsulating the header of the packet, and based on the information associated with the first next hop, that the packet is to be routed based on a particular segment routing policy, of one or more segment routing policies associated with the first device;

remove the header of the packet;

add, without performing a lookup process and based on determining that the packet is to be routed based on the particular segment routing policy, a new header to the packet,

wherein the new header includes at least one of a first segment identifier list that identifies a first path associated with the first next hop of the at least one next hop or a second segment identifier list that identifies a second path associated with a second next hop of the at least one next hop, and

wherein the new header further includes a first destination address associated with the first segment identifier list or a second destination address associated with the second segment identifier list; and

cause, based on the new header, the packet to be routed via a particular path associated with the particular segment routing policy.

9. The first device of claim **8**, wherein the one or more processors are further to:

receive policy data identifying the one or more segment routing policies, including the particular segment routing policy, that are associated with particular paths that include respective next hops.

10. The first device of claim **8**, wherein the particular segment routing policy identifies a particular next hop and a particular segment identifier list that identifies the particular path.

11. The first device of claim **8**, wherein the header further includes data identifying the second next hop,

wherein data identifying the first next hop and the data identifying the second next hop is included in the header based on advertising a reachability associated with the first next hop and the second next hop, and

wherein the one or more processors are further to:

determine routing from data identified in the first next hop and the second next hop.

12. The first device of claim **8**, wherein the first segment identifier list is associated with the particular segment routing policy.

13. The first device of claim **8**, wherein the header that is decapsulated is an extra Internet protocol version 6 (IPv6) header.

14. The first device of claim **8**, wherein the packet is associated with an application of the second device.

15. A non-transitory computer-readable medium storing a set of instructions, the set of instructions comprising:

one or more instructions that, when executed by one or more processors of a first device, cause the first device to:

provide, to a second device, information associated with reachability related to at least one next hop;

receive, from the second device, a packet including information associated with a first next hop of the at least one next hop;

decapsulate a header of the packet;

determine, based on decapsulating the header of the packet, and based on the information associated with the first next hop, that the packet is to be routed based on a particular segment routing policy, of one or more segment routing policies associated with the first device;

remove the header of the packet;

add, without performing a lookup process and based on determining that the packet is to be routed based on the particular segment routing policy, a new header to the packet,

wherein the new header includes at least one of a first segment identifier list that identifies a first path associated with the first next hop of the at least one next hop or a second segment identifier list that identifies a second path associated with a second next hop of the at least one next hop, and

wherein the new header further includes a first destination address associated with the first segment identifier list or a second destination address associated with the second segment identifier list; and

cause, based on the new header, the packet to be routed via a particular path associated with the particular segment routing policy.

16. The non-transitory computer-readable medium of claim **15**, wherein the one or more instructions further cause the first device to:

receive policy data identifying the one or more segment routing policies, including the particular segment routing policy, that are associated with particular paths that include respective next hops.

17. The non-transitory computer-readable medium of claim **15**, wherein the particular segment routing policy identifies a particular next hop and a particular segment identifier list that identifies the particular path.

18. The non-transitory computer-readable medium of claim **15**, wherein the header further includes data identifying the second next hop,

wherein data identifying the first next hop and the data identifying the second next hop is included in the header based on advertising the reachability associated with the first next hop and the second next hop, and

wherein the one or more instructions further cause the first device to:

determine routing from data identified in the first next hop and the second next hop.

19. The non-transitory computer-readable medium of claim **15**, wherein the first segment identifier list is associated with the particular segment routing policy.

20. The non-transitory computer-readable medium of claim **15**, wherein the packet is associated with an application of the second device.

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